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For the Patent- and Registration Office

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Avgift
Fee

1

1 Title of the Invention

Method and arrangement in Self-Organizing Cooperative Network

2

2.1 Background Technology

The invention relates to wireless communication, and in particular it relates to a relaying deployment in a cellular system.

Advanced antennas and spatial coding: Methods to enhance system performance in a cellular is very active research area. One such method is to employ multiple antennas at the basestations (*BSs*), and thereby provide valuable diversity gains that mitigate any channel fluctuations imposed by fading. In downlink, (from BS to a mobile stations (*MS*)) so called transmit diversity can be employed and in uplink, (form MS to BS) receiver diversity can be used. Of course, the MS may also be equipped with multiple antennas, but a MS is generally space limited (which inherently limits the number of antennas at the MS) and therefore the BS solution is often to prefer. Many well known schemes exist both for receiver and transmitter diversity. For receiver diversity, selection diversity, maximum ratio combining or interference rejection combining may be used. For the newer transmit diversity area, delay diversity, Alamouti diversity, Coherent combining based diversity are possible options.

Transmit diversity, and in particular Alamouti diversity, belongs to a class of coding schemes, that are often denoted space-time coding (*STC*). In STC schemes, it is generally assumed that the transmitter has multiple antennas and the receiver have only one or alternatively multiple antennas. Any transmitted signal is then encoded over the multiple transmit antennas and sometimes also in time. With multiple antennas at both transmitter and receiver side, the channel is often denoted a Multiple Input Multiple Output channel (*MIMO*). A MIMO channel can be used mainly for two reasons, either for diversity enhancements, i.e. providing a more robust channels under channel fluctuations, or for so called spatial multiplexing, i.e. providing a set of parallel and multiplexed MIMO subchannels. The benefit of spatial multiplexing is that extremely high spectrum efficiency is achievable. A background on MIMO communication is given in

Repeaters: Another well-known method is to deploy repeaters in areas where coverage is poor. The basic operation for the repeater is to receive a radio signal, amplify it, and retransmit it. Repeaters may use the same frequency for reception and transmission, or optionally shift the transmit frequency for increased output-input isolation avoiding risk for feedback and oscillations.

Cooperative Relaying: (a.k.a. Virtual antenna arrays) Traditionally, the repeaters are fairly unintelligent. However, more recently, the idea of cooperative relaying with smarter repeaters (or relays) has received some interest. The idea is that relays can cooperate in forwarding a signal from a transmitter to a single receiver (but multiple receivers in [69]). The cooperation may for instance involve aspects of coherent combining, STC (e.g. Alamouti diversity), and be of regenerative (decode and forward data) or non-regenerative (amplify and forward data) nature. The number of hops is limited to two hops, i.e. one hop to the relay station(s), and one hop to the receiving station.

One special and interesting type of Cooperative relaying (or virtual antenna arrays) is when MIMO is exploited. This has been studied extensively by Dohler et al., e.g. in [57].

2.2 Summary of the invention

Cooperative relaying comprises transmitting, relaying and receiving stations. Generally there is at least one relay station, one transmitting station and one receive station, but potentially multiple receive and transmit stations can be envisioned as well.

For real system integration of Cooperative relaying it has traditionally been assumed that there exists a control mechanism for controlling the involved relay stations. It is the users with active sessions that the control mechanism operates upon. The purpose of the control mechanism is to manage the network such that the most optimum relays are activated and/ or their respective transmit power are optimized in forwarding data to the user(s) with an active session. The relay transmissions may also respond in other ways depending on feedback to the relay of the link quality between the relay and the (mobile) user, such as changing complex phase of the forwarded signal for coherent combining purpose or by adapting space time coding operation. The need of control obviously arises primarily due to mobility and resulting topology changes. The procedure of relay activation and dependency of time is schematically illustrated in Figure 1, where different sets of relay stations are activated at time T_1 and T_2.

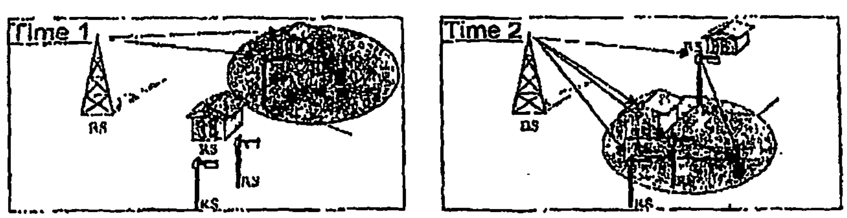

Figure 1

Another problem is how to employ session or user centric control of the relays when multiple receivers are present as they may have conflicting optimal relay configurations and parameters settings. The optimality may differ with respect to which relay is active, transmit power levels, channel assignments, space time coding options and phase adjustment etcetera used. The procedure of relay activation and dependency of multiple users is schematically illustrated in Figure 2, where different sets of relay stations are activated for each user.

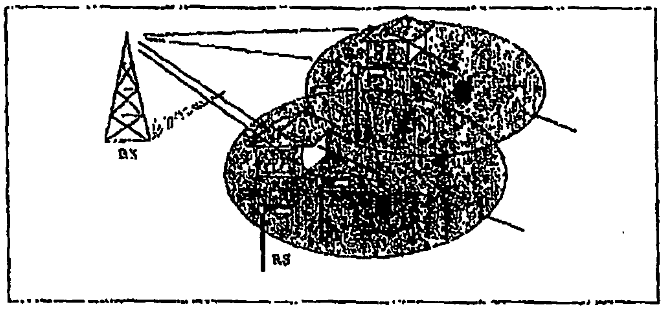

Figure 2

The overall control procedure that is used in state of the art of cooperative relaying in a cellular scenario (or similar) requires that control messages are exchanged. The problem with this is that the amount of control data may be excessive, especially when topology changes frequently due to that the mobile user moves fast and has to control the relays transmit parameters (e.g. power) or change relays frequently. More importantly, even if topology does not change, the changes in radio propagation can be considerable and dictate fast power control and associated fast control message exchange towards the relays. Other parameter that may be adjusted with often depends on cooperation scheme, but can for instance include phase and space time coding options. A significant problem is that it is not clear from the state of the art how to handle multiple receive stations with conflicting relay parameter settings for the same relay stations. The drawback of the whole notion of controlling relays is that it is utterly complex, it requires a new protocol (logically between the relays and the MS) and it consumes radio resources (that could be used for sending data).

The invention addresses a special relay architecture that it is similar to so called Cooperative relaying (also referred to as virtual antenna arrays, cooperative diversity, etc.) [16]. The common part is the idea of incorporating aspects of advanced antennas together with relaying. In the following, the area of advanced antennas is discussed first, and subsequently, the state of the art with respect to cooperative relaying is considered.

The idea is that relay channels are organized in such way that their channels overlap spatially. This may be organized in a centrally or distributed manner. There are two main parts, relay channel selection and gain factor selection of forwarded signal. Subsequently, the relays operate as simple repeaters (non-regenerative normally, but regenerative whenever possible) for some BS, and the relay parameters do not change as a response to a single (or multiple) mobile users instantaneous link quality. Each mobile station may make soft associations to multiple relays at each time instance, and while moving; continuously updating associations based on e.g. signal quality parameters. The invention allows MIMO communication schemes, such as spatial multiplexing, to be implemented with a single antenna receiver, whereas the BS has multiple antennas and multiple relay channels are exploited. A receiver to transmitter feedback, without passing the relays, allow the transmission to be adapted based on instantaneous link conditions. The invention may be used in downlink or in uplink for a cellular system.

Keywords: Multiple relay coverage overlap, Soft association, Cooperative MIMO (or IRC/MRC), 2-hop, Self-organization (or by hand), Non-regenerative, Orthogonal channels, (fixed relays). Relay controlled Cooperative relay network management.

3 Detailed description

3.1 Detailed Technical Description of the Invention

3.1.1 Overview.

The most general architecture is given in Figure 3, where both the receivers (i.e. users) as well as relays are equipped with multiple antennas. Although not shown here, relays may use multiple channels for relaying, e.g. one for each receive antenna. A somewhat more simplified architecture is shown in Figure 4, where receivers and relays have single antennas. However, the case with a single receiver (user) is perhaps the most likely one. The basic operation is that the transmitter sends a data stream (possibly through trough a weighting matrix **U** and subsequently over multiple transmit antennas). The relays forwards any received signal without changing relay transmit parameters such as channel, signal gain factor (and optionally any coding). However, the relays may try to decode the received signal or in other ways improve the signal fidelity prior forwarding the signal. The receivers, receives signals forwarded from the multiple relays and doing so over different channels. The channelization may e.g. be in the frequency or time domain. The receivers may also receive the direct signal from the transmitter channel.

After receiving signals, that are sent over multiple channels, the receiver processes the signals. Depending on transmit method used, the processing block may involve any combination of combining, joint decoding, and multiplexing decoded data. Based on the quality of the received signal, the receivers may send feedback to the transmitter. The transmitter may based on this feedback respond to changes in various transmit parameters, including antenna weights, modulation(s) and coding(s), transmit power. In particular, the transmitter may opportunistically decide whom to send data to based on instantaneous channel quality conditions. In this manner, valuable multi-user diversity gain can be offered in conjunction with the benefits offered by relaying. If the transmitter is silent, e.g. due to that there is no data to send, transmitter associated relays may stop the forwarding.

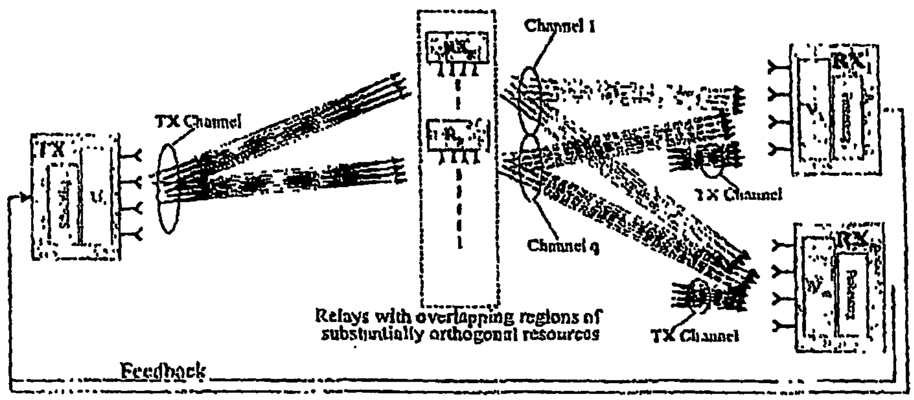

Figure 3

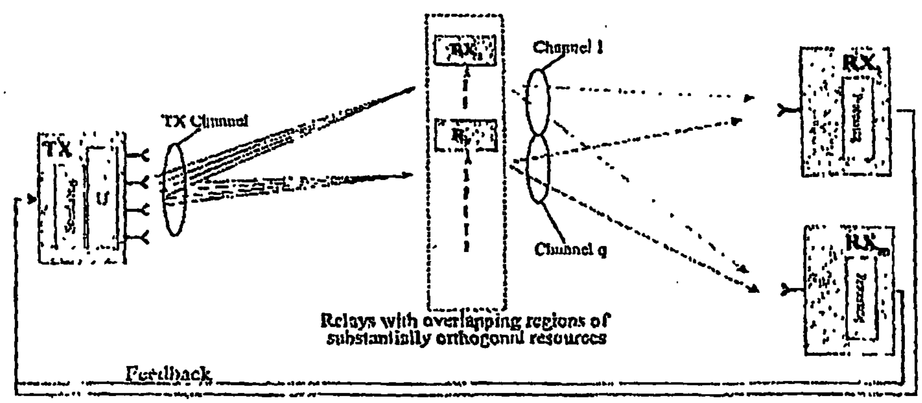

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Figure 4

Figure 5 illustrate how relays can be distributed, here exemplarily attached to lamp poles, and relay resources, such as channel and transmit range are organized. It is seen that relay coverage for the substantially orthogonal channels are overlapping. It is also shown that a channel can be reused multiple times within the same cell such as channel q in Figure 5. Channels may of course also be spatially reused between cells. The relays may be attached not just to lamp poles but also to houses, towers, etc.

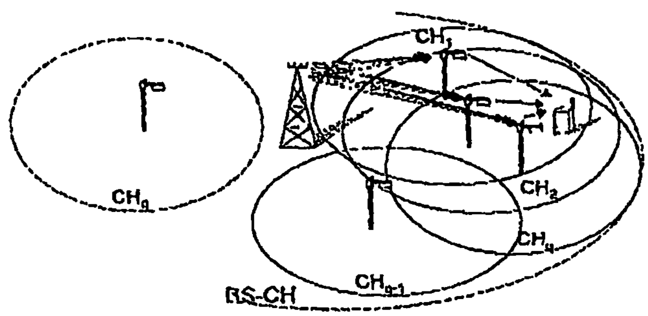

Figure 5

The overlapping coverage regions may be organized in different ways as shown in Figure 6. A benefit for Case A over case B is that the quality of a relay link will generally be better thanks to the proximity of relays. Case B, however has the benefit that clusters of relays can be replaced with a single relay entity having the same number of antennas. The antennas can then be connected by cables, optical fibres or even short-range wireless links.

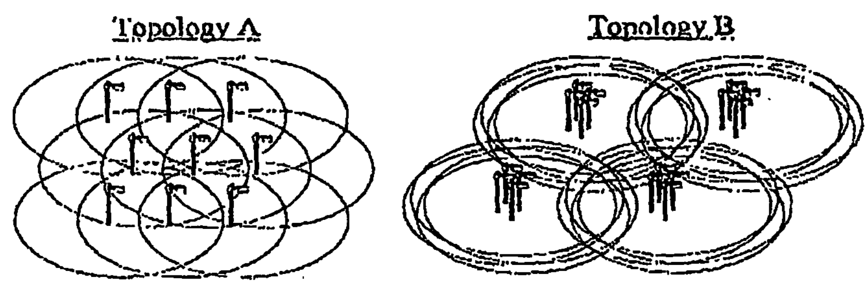

Figure 6

To be more specific, the invention incorporates several functions listed below which are addressed in subsequent sections.

- Relay organisation for overlapping coverage regions
- Soft association to relay channels
- Forwarding at the relay

- Communication scheme and Decoding at the receiver
- Receiver to transmitter feedback

3.1.2 Functions

3.1.2.1 Relay organisation for overlapping coverage regions

One important aspect of the whole idea is self-organization of relay stations. The relays organize themselves such that substantially orthogonal channels from different relays overlap spatially. This is mainly achieved by selecting a combination of signal gain factor and channel. Although signal gain factor is the main focus in the invention, another alternative option is to select relay transmit power. However, if selecting transmit power, care must be taken not to distribute noise when the input signal is weak, or plainly accept that a noisy signal is forwarded. The self-organization can take place when, the network is initiated, when a new node is inserted in the network or a relay node fails. However, the transmitter may, based on long term statistics of previous communication with users, suggest some actions for the relay to perform, such as increasing the signal gain factor or changing the channel. Note that for this option, the relay parameters are not changed in response to ongoing sessions to adapt to a specific user. It is rather to be seen as a adaptive cell planning operating on a slow time basis.

The algorithm for self-organization can be constructed in several ways. In the following, to basic exemplifying architectures with algorithms that will be discussed are a centralized and a distributed version of relay parameters organisation.

<u>Centralized operation</u>
The basic operation is indicated in Figure 7. For simplicity, we assume that the whole relay system is started up at the first time. First the relays are initiated, and each relay starts by detecting which relay neighbours are available. When doing this, path loss information (and optionally position information) can be collected from the neighbouring relays. In a next step, the relays report the collected data to a central entity responsible for one or more BSs that then determines the relay configuration with respect to signal gain factor and channel allocation, and also with which BS to receive and to associate with. The relays are then updated based on the determined parameters and activated to start forwarding signals received from a BS.

As this solution is centralized, an exhaustive search of relay channels could be performed if the number of relays as well as the number of channels are not to large. Otherwise, a centralized heuristic dynamic channel allocation scheme could be used. Off line computation can be used for the centralized case, so complexity is not a major hurdle. If a new relay nodes arrives to the network, or a relay node fails, new relay configuration parameters can be determined and then set in the relays. Hence, the relay neighbour discovery process is something that can continuously operate, even when the phase of forwarding is taking place. Preferably, the relay-to-relay communication takes place in channels that does not interfere with user data.

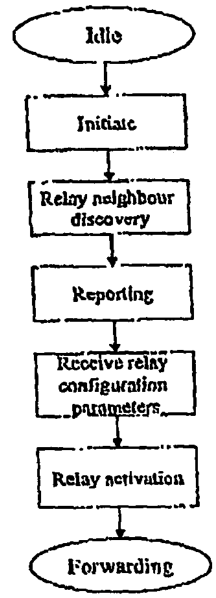

Figure 7

Distributed operation

Another possibility is to perform a distributed channel and signal gain factor allocation scheme. This is by necessity not as good as a centralized version, but has the advantage that it does not require any reporting of neighbour related information to any central entity. Many different algorithms can be envisioned here, but we exemplify the distributed case with a fairly simple scheme. After initiation of the systems, relays discover their neighbours (similar to the centralized case). When doing so, path loss can be estimated between the relays. Based on the path loss, and signal quality from the transmitter, signal gain factors are determined. One rule that could be applied is that at least N Neighbours should be reached but with an upper transmit power constraint limiting the possible number of relays. For transmission towards a basestation, i.e. cellular UL, the signal gain factor could also be set in response of the link quality to a selected BS.

Next, a tentative channel is randomly selected. The selected channel is then sent to the N selected relays. Similarly each relay, receives information from adjacent relays on which channels they are using. Each relay station examines the set of selected tentative channels and assigns a channel reallocation probability corresponding to each channel. If a relay sees a relative high frequency selection of a specific channel, i.e. relative other channels, it will result in that this channel is assigned a higher reallocation probability. The reallocation probabilities (or reallocation probability vector) are then distributed to the neighbours. When receiving one or more reallocation probability vectors, this guides each relay station to randomly give up the old channel. One may also include a preferred channel probability vectors to guide the selection of the new channel, increasing the probability that a previously unloaded or lowly loaded channel is selected. This continues until an optimization criterion is fulfilled or another delimiter such as the number of iterations exceeds a maximum threshold. The optimization criteria may e.g. be to strive to distribute the use of channels such that all channels are used more or less equally. One simple method is to try o minimize the variance, and if the variance does not change significantly over multiple iterations, one stops the iterations.

Although a probabilistic approach has been used here, one may also envision using a more deterministic approach, where a relay recommend another relays to move form one channel to another. Moreover, one can also envision that transmit power can jointly be assigned together with channels in a distributed manner.

Apart from aforementioned main method, many other well known distributed channel allocation methods should be possible to deploy. Note that it is not extremely critical if the same channel is used by multiple relays, it only means that the SNR increases somewhat in an average sense. With respect to the MIMO scenario, signal processing takes place in the receiver, and using the same channel by multiple relays is transparent form the receiver point of view. However, from performance point of view, it is preferable to use as many of the available channels as possible in any given position.

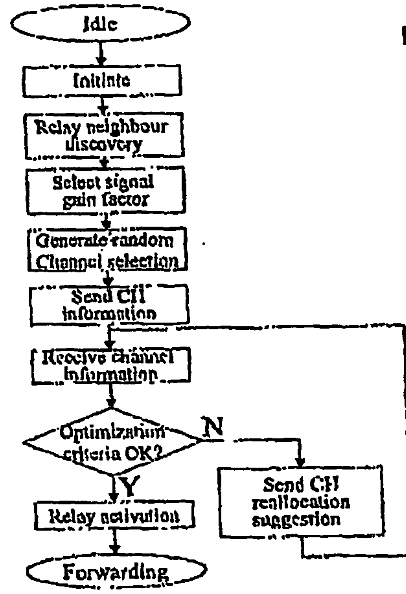

Figure 8

3.1.2.2 Soft association to relay channels

Another important aspect of the invention is that a mobile user with an active session perform soft receiver internal association to any good relay channels while traversing through regions with overlapping relay channels.

The receiver may be limited to use all available channels, and can only use a subset of those available. This may be dictated by hardware limitations or for power consumption point of view. It is then important that the relay dynamically select those channels that maximize the performance at any given moment. In particular, the channels may be selected in response to application used, e.g. with respect to BW requirements. I fonly two channels are need to fulfil the BW requirement, it make little sense two use all available channels. Instead, other users may use free channels. The flowchart in Figure 9 illustrates this operation from the receiver point of view.

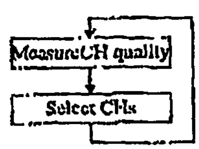

Figure 9

3.1.2.3 Forwarding at the relay

The relays forwards any signals received from the transmitter. A system comprising relay stations may use a threshold criteria for a minimum required SNR for forwarding received signal. In this manner, forwarding of to noisy signals can be mitigated.

A transmitter may also signal that no data will be sent, whereby forwarding from the relays cease until data is anew transmitted.

The relay may also incorporate various encoding methods. For instance, a signal may be delayed by a random small time, sufficient to induce artificial frequency selectivity (This is known as delay diversity). Another option is to use space time coding schemes, such as Alamouti diversity. Here we assume that the relay receives two units of data, called part A and part B, on which Alamouti transmit diversity encoding is performed. To start with, a relay assumes the role of one of the antennas in Alamouti diversity. If it assumes the role of antenna 1, it transmits part A and a conjugated version of part B. If instead the relay assumes the role of antenna 2, it transmits part B first and then a negated and conjugated version of part A. Other type of space-time coding methods may also be deployed. It should be emphasized that any of the parameters used in forwarding does not depend on which user is currently using the signal forwarded by the relay.

3.1.2.4 Receiver to transmitter feedback

As seen in Figure 3 and Figure 4, a receiver (or potentially several receivers) can feed back information to the transmitter, so the transmitter can adapt its transmit parameters.

The feedback information can be of different type depending on where the link control mechanism resides. If the receiver has significant part of the link control, then it may decide a link mode, comprising coding and modulation scheme, for the transmitter. It may also decide which transmit weights the transmitter should use. The transmit weights are particularly relevant for the MIMO case, but can also used in a beamforming context. The receiver may alternatively forward raw channel state information (such as SNRs) to the transmitter, and the transmitter determines which transmit parameters (link mode, transmit weights, transmit power etc.) to use.

If multiple receivers are concurrently feeding back information to control the communication link, then the transmitter may decide to schedule traffic to the instantaneously "best" receiver or alternatively when multiple antennas are available at the transmitter to send to multiple receivers concurrently. In particular, the transmitter can respond on user specific fading channel fluctuations or interference fluctuations in an opportunistic manner.

Although BS transmit power could in principle be tuned it is not the prime parameter to tune, as it would result in fluctuating relay coverage radius. It is rather so that the signal gain factor is set under the assumption that the BS uses some transmit power level, yet the relay powers will be limited by their maximum transmit power level. However, transmit power could occasionally be tuned to manage any direct link used between, e.g. a transmitting BS and receiving MS.

3.1.2.5 Communication scheme and Decoding at the receiver

3.1.2.5.1 Communication signal processing schemes

Several signal processing schemes can be employed. Assuming DL, a BS with multiple antennas may use MIMO based communication to the MS. The benefit of MIMO is that it can, apart from offering diversity, also be tuned to offer spatial multiplexing that in turn yields very high spectral efficiency. Alternatively, when the BS only deploys one antenna, the communication to a MS degenerates to a SIMO channel. Even so, the receiver may combine the received signals through maximum ratio combining (MRC) or interference rejection combining (IRC). If the relays imposes some STC method on the forwarded signals, the receiver may need to consider this at the decoding.

3.1.2.5.2 (MIMO) Decoding

Let's assume that MIMO based communication is considered. The transmitter sends a vector **T** over channel matrix **H**, where each row corresponds to one or more relays using the same relay channel and there are as many relay channels as there are rows in the channel matrix. Each relay adds noise, which here corresponds to a noise vector **N**. Each relay subsequently multiplies the useful signal (i.e. a superposition of the signal vector T) with the predetermined signal gain factor (or ensures that the total output power including signal power and noise power does not exceed the maximum power level) is used at the relay. The transmitted signal is then attenuated by the path loss between the relay and the receiver. The signal gain factor and the attenuation can be combined into a diagonal matrix **A**. The receiver in turn adds noise vector **W** to the signal being received from the relays. The communication link can now be modelled as

$$\mathbf{R} = \mathbf{A} \cdot (\mathbf{H} \cdot \mathbf{T} + \mathbf{N}) + \mathbf{W}.$$

If a direct link between the transmitter and the receiver is utilized, this can also straightforwardly be incorporated in the matrix formulation by adding a row where the entry in **A** is set to one and the new row in **B** is the direct link channel.

The above equation system can be diagonalized, e.g. by using singular value decomposition MIMO approach on the matrix $\mathbf{A}\cdot\mathbf{H}$, similar to what is well-known in traditional MIMO. However, the matrix formulation in this invention differs from the classical MIMO system linear equation system formulation, which has the form $\mathbf{R}=\mathbf{H}\cdot\mathbf{T}+\mathbf{W}$. For the invention with SVD based MIMO, it means that the transmitter will apply a unitary weight matrix **U** and the receiver multiplies with the Hermitian of a unitary weight matrix **V**. The diagonalization allows the receiver to directly receive a number of parallel self-interference MIMO subchannels.

For a receiver with multiple antennas, as in Figure 3, it may use various forms of combining and decoding scheme including any well-known method such as MMSE and Single user detection (SUD, multiple user detection (MUD) (exemplified by Successive Interference Cancellation or parallel Interferences cancellation). The purpose of doing this is that the signal quality can be enhanced in the receiver for decoding.

3.1.3 General issues

So far in the invention description, the issue on antenna design has not been discussed. In the general case, omni-directional antennas may do at the relays. However it may be beneficial to used directional antennas that can be directed towards a selected basestation. Given directional antennas, it is evident that this may implemented in many ways, including fixed beamforming, or adaptive antennas. For the adaptive antenna case, the beamforming may be accomplished for downlink from the BS solely by the relay by setting its receive antenna weights to maximize carrier to interference ratio, preferably also suppressing undesirable interference.

For relays with multiple antennas, they may use various forms of combining and decoding scheme including any well-known method such as MMSE and Single user detection (SUD, multiple user detection (MUD) (exemplified by Successive Interference Cancellation or parallel Interferences cancellation). The purpose of doing this is that the signal quality can be enhanced in the relay prior forwarding the signal.

A particular interesting case for the relay channels is to use the large bandwidth offered by unlicensed frequency bands. This is particularly beneficial when considering the MIMO scenario.

To enhance the capacity offered by a basestation, the basestation (or BS site) may be support multiple sectors. Each sector will then according to the invention use different relays.

The invention is not limited to any particular modulation scheme. Multicarrier modulation schemes, such as Orthogonal Frequency Division Multiple Access (*OFDM*) may also be used. This means that one part of the spectrum (i.e. sonme OFDM subcarriers) are used for one user and another part of the spectrum for another user. This may be generalized to multiple users.

Although the discussion has been focused on downlink in a cellular system, the same idea may used for UL in an analogous manner. The relay should preferably only send when the SNR exceeds a minimum threshold level, or else they will send signals with low SNRs. The relay power for UL operation is also set differently; it is set such that transmissions reach the intended receiver such as a Basestation with a desired signal quality. The relay coverage overlapping, as discussed up to now, does now not regard transmission, but rather reception. The channel allocation can be the same as for the transmission. The transmitting MS, may also invoke different transmit power on different channels. This can be controlled by providing feedback from the BS (i.e. the receiver) based on the link quality. The scenario with a transmitter with a single antenna and sending over the different relay channels is shown in Figure 10. Also more complicated scenarios, similar to Figure 3, with multiple antennas at the transmitter and the relays can be envisioned. Moreover, analogous to Figure 4, multiple transmitters sending data to a single BS is possible.

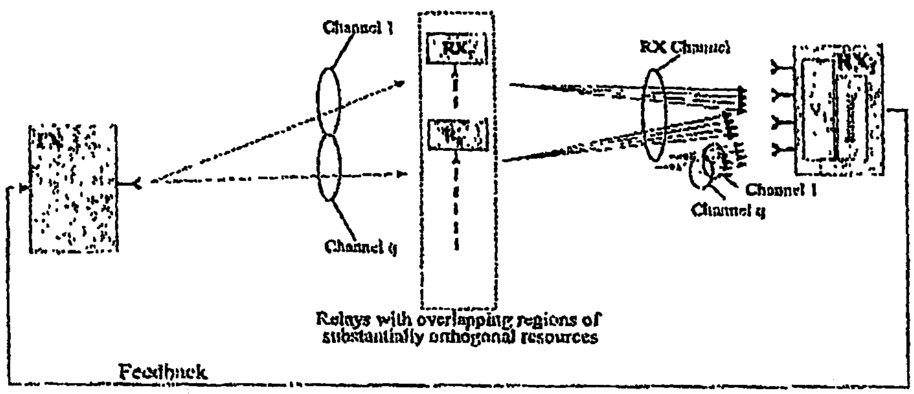

Figure 10

3.2 Advantages of the Invention

The performance benefits that characterize cooperative relaying methods are achieved while removing the control complexity between relays and the mobile station. It is also straightforward to implement MIMO with only one antenna in the mobile station, but with very low overall system complexity. Alternatively, instead of MIMO, receive diversity may be implemented.

It is also possible to have adjacent users in the downlink, using the same relays, and adapt transmissions to one or more users by employing feedback to the BS. The same is true for the reverse, i.e. in UL. Then multiple users can share and send information passing through the same relay. The separations between multiple users is done by spatial signal processing in the receiving BS employing multiple antennas. In particular can opportunistic communication, i.e. selecting users or user MIMO substreams based on instantanpus carrier to interference conditions, be offered together with the benefits offered by relaying.

4 Details on cooperative relying

4.1 Cooperative relaying background

4.1.1 Cooperative Communication Topologies

One may divide the various cooperation schemes based on who has data to send, to whom and who cooperates. A number of topologies reflecting this division has been devised within the area of information theory, see [1] and even better, [16] page 37-39, 41-44.

The topologies shown below, and discussed subsequently, shows where traffic is generated, who is the receiver and the path for radio transmissions.

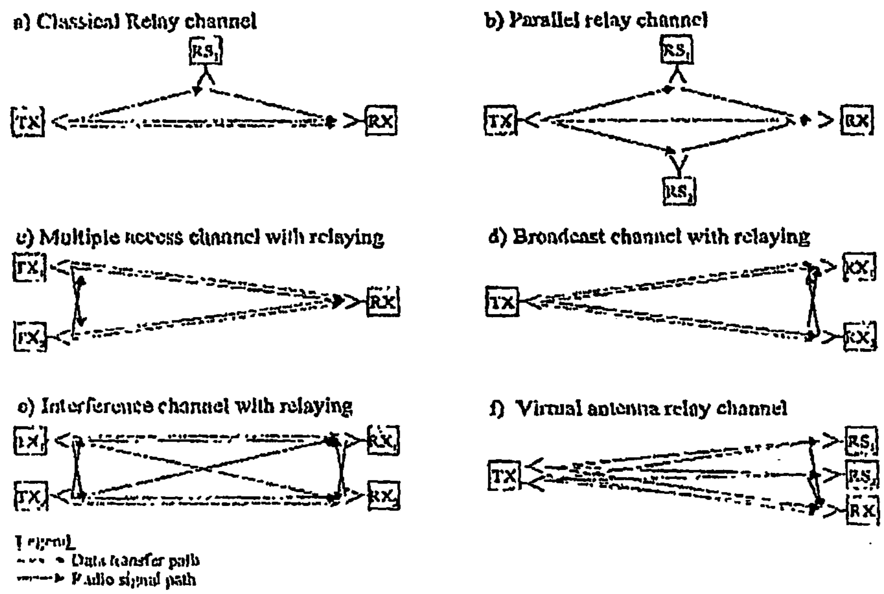

Figure 11 Cooperation topologies with relaying

Classical Relay Channel

The classical relay channel consists of a source that wishes to communicate with a destination through the use of relays, see Figure 11 and topology a). The relay receives the signal transmitted by the source through a noisy channel, processes it and forwards it to the destination. The destination observes a superposition of the source and the relay transmission. The relay does not have any information to send; hence the goal of the relay is to maximize the total rate of information flow from the source to the destination. The relay channel has been studied in [1], [4] and in [11] where receiver diversity was incorporated in the latter.

Parallel relay channel

In wireless systems employing repeaters (such as cellular basestation with supporting repeaters) with overlapping coverage, a receiver may benefit of using super-positioned signals received from multiple repeaters, see Figure 11 and topology b). This is something that happens automatically in systems when repeaters are located closely. Recently, information theoretical studies have addressed this case.

In [54] and [55], Schein has performed information theoretical study on a cooperation-oriented network with four nodes, i.e. with one transmitter, one receiver and only two intermediately relays.

In [47], Hunter briefly discusses the same topology as the parallel relay channel, but over arbitrary number of hops, and then calls it "Multiroute diversity". He discards it as inferior to multihop diversity (the classical relay channel with receive combining in each relay), and does not investigate this topology any further.

In [71], Gastpar denotes the parallel relay channel for "The multiple-relay channel", and indicates that relays can be "pooled" either closely around the source, around the destination or both. No methods how to accomplish this is given.

In [17], Laneman perform an information theoretical study, based on random coding arguments, of the parallel relay channel topology (but calls it "Space time coded cooperative diversity"). Each relay receives and decodes a signal prior coding with a suitable space-time code.

Multiple-access Channel with Relaying

(a.k.a. as Multiple access channels with generalized feedback)

This concept has been investigated by several researchers lately and is represented by topology c) in Figure 11. The idea is that two users cooperate, i.e. exchange the information each wants to transmit, and subsequently each user sends not just its own information but also the other users information to one receiver. The benefit in doing so is that cooperation provides diversity gain. There are essentially two schemes that have been investigated; cooperative diversity and coded cooperative diversity. Those studies are primarily found in [5]-[53]. With respect to diversity, various ideas has been suggested, such as Alamouti diversity, receiver diversity, coherent combining based diversity, rate compatible puncture code (*RCPC*) coded transmissions.

Broadcast Channel with Relaying

The broadcast channel with relaying, topology d) in Figure 11, is essentially the reverse of topology c), and is therefore not addressed individually any further.

Interference Channel with Relaying

The interference channel with relaying is an extension of topology c) in Figure 11, to two receivers. This has e.g. been studied in [40], [41], but without cooperation between the receivers.

Virtual Antenna Array Channel

A slightly different idea from above, shown in Figure 11 topology f), is presented in [63]-[68] and partly also in [70]. In this concept, (significant) bandwidth expansion between a communicating station and adjacent relay nodes is assumed, and hence non-interfering signals can be transferred that retain phase and amplitude information. With this architecture, MIMO communication (but also other space-time coding methods) is enabled with a single antenna receiver. The topology may equivalently be used for transmission.

4.1.2 Cooperative communication signal processing strategies

It is clear that various signal-processing strategies can be implemented in above topologies and has also been done. It is apparently often hard to separate the topology form the signal processing and communication scheme, but the following represent one approach.

Classical relay channel & parallel relay channel
Basic repeater: This is a traditional non-regenerative repeater without any kind of intelligence.

Classical relay channel & partial parallel relay channel, Selection diversity: In this scheme, a single relay is selected on a dynamic basis, either based on instantaneous or average channel conditions.

(Parallel relay channel), Relay induced transmit diversity: Relay stations may use non-regenerative or regenerative relaying. They may have rudimentary knowledge of the radio channel to the transmitter and receivers or precise information. The relays are assumed to be able to perform rudimentary signal processing operation (apart from possible decoding). Operations may include, shifting, delaying, complex conjugating, even coding may be included. A characteristic of those signal processing schemes are that they have to be able to operate in a single channel from relay to receiver. Within this scheme, Alamouti diversity, other STC based schemes, delay diversity, delay diversity and coherent combining diversity can be incorporated.

Virtual Antenna Array Channel: Multi sensor processing: This scheme assumes orthogonal channels between the relays and the receiver and hence allow any signal processing scheme and communication scheme involving multiple sensor information. Examples of this include any of the traditional MIMO schemes, but also those that include aspects of interference rejection.

Note that the relays do not receive instruction to receive and relay data, they simply act as repeaters independent from single mobiles mobile users and their sessions.

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CLAIMS:

1. A system for wireless communication adapted for relaying, said system comprising of at least two relay stations **characterised in** that substantially orthogonal resources overlap in space

2. The system according to claim 1, **wherein** relays arrange the substantially orthogonal resources in a self-organizing manner.

3. The system according to claim 1, **wherein** substantially orthogonal resources are arranged manually.

4. The system according to claim 1, **wherein** the substantially orthogonal resources are any combination of at least selection of channel, phase, delay and other encoding parameters.

5. The system according to claim 4, **wherein** the substantially orthogonal resources for DL also include signal gain factor parameters.

6. The system according to claim 1, **wherein** a MS makes soft internal association with at least on relay and receives the at lest one substantially orthogonal resource.

7. The system according to claim 6, **wherein** the MS uses the at lest one substantially orthogonal resource and feedback quality indication to the BS.

8. The system according to claim 7, **wherein** the BS respond on the feedback quality indication and adjust transmit parameters to fulfil communication objectives.

9. The system according to claim 8, **wherein** antenna weights are adjusted.

10. The system according to claim 1, **wherein** the relays uses a wireless communication protocol for self-organization.

11. The system according to claim 4, **wherein** the substantially orthogonal resources uses long term communication feedback for parameters setting.

12. The system according to claim 8, **wherein** the BS respond on the feedback quality indication and select a set of users and transmit parameters optimizing an objective function representing the communication performance.

13. A method system for deploying relaying in a wireless system, said system comprising of at least two relay stations, the method **characterised in** that substantially orthogonal resources are arranged to overlap in space

14. The method according to claim 13, **wherein** relays arrange the substantially orthogonal resources in a self-organizing manner.

15. The method according to claim 13, **wherein** substantially orthogonal resources are arranged manually.

16. The method according to claim 13, **wherein** the substantially orthogonal resources are any combination of at least selection of channel, phase, delay and other encoding parameters.

17. The method according to claim 16, **wherein** the substantially orthogonal resources for DL also include signal gain factor parameters.

18. The method according to claim 13, **wherein** a MS makes soft internal association with at least on relay and receives the at lest one substantially orthogonal resource.

19. The method according to claim 18, **wherein** the MS uses the at lest one substantially orthogonal resource and feedback quality indication to the BS.

20. The method according to claim 19, **wherein** the BS respond on the feedback quality indication and adjust transmit parameters to fulfil communication objectives.

21. The method according to claim 19, **wherein** antenna weights are adjusted.

22. The method according to claim 13, **wherein** the relays uses a wireless communication protocol for self-organization.

23. The method according to claim 16, **wherein** the substantially orthogonal resources uses long term communication feedback for parameters setting.

24. The method according to claim 20, **wherein** the BS respond on the feedback quality indication and select a set of users and transmit parameters optimizing an objective function representing the communication performance.

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